Using Cybersickness Indicators to Adapt Navigation in Virtual Reality: A Pre-study

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ABSTRACT

We propose an innovative method to navigate in a virtual environment by adapting the acceleration parameters to users in real time, in order to reduce cybersickness. Indeed, navigation parameters for most navigation interfaces are still determined by rate-control devices. Inappropriate parameter settings may lead to strong sickness, making the application unusable. Past research found that especially accelerations should not be set too high. Here, we define the accelerations as a function of a cybersickness indicator: the Electro-Dermal Activity (EDA). A pre-study was conducted to test the effectiveness of our approach and showed promising results where cybersickness tends to decrease with our adaptive navigation method.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual reality; Human-centered computing—Interaction design—Interaction design process and methods—User centered design

1 INTRODUCTION

Navigation interfaces and techniques are required to explore virtual environments that can be infinite [11]. However, undoubtedly, navigation in virtual reality differs from that in the real world. For instance, navigation tasks are the source of a well-known virtual reality issue: cybersickness. Past studies showed that some navigation methods were more efficient in terms of navigation performance while they should use some specific acceleration parameters to reduce cybersickness [4]. However, with specific parameters, these navigation methods loose their effectiveness for navigation.

We aim at reducing cybersickness while still allowing efficient navigation in virtual reality. We propose to adapt in real time navigation parameters from online cybersickness indicator's measures.

1.1 Related Work

1.1.1 Cybersickness

Many studies attempt to understand cybersickness while others seek to decrease its effect. Cybersickness occurs during or following virtual immersion and is similar to the discomfort caused by motion sickness. It can be evaluated through both subjective and objective ways. Subjective measurements include the well-known Simulator Sickness Questionnaire (SSQ) [6]. Postural stability allows to estimate and predict cybersickness [3]. Objective evaluation include measurements of the Electro-Dermal Activity (EDA) [7] and the calculation of the Motion-Sickness Dose Value (MSDV) [13].

1.1.2 Navigation Methods

Many works explore how to tune navigation parameters such as the acceleration and the maximum speed in order to reduce cybersickness. In any case, smaller linear and rotational accelerations are recommended [9]. Sargunman et al. [12] evaluated a semi-natural navigation method with amplified rotation factors and found that their method works well when users are seated. Basting et al. [2] exposed that the field of view (FOV) changes the perceived vection. From this statement, Fernandes and Feiner [5] explored an innovative solution where the field of view is dynamically modified according to the displacement in the virtual environment. Argelaguet Sanz [1] proposed and evaluated a speed adaptation algorithm that automatically adjusts the navigation speed from the spatial relationship between the user, the environment and the optical flow.

1.2 Contributions

Cybersickness effects are user-dependent but from the literature, virtual reality applications use navigation methods with static parameters, i.e., that do not depend on the user. Here, we propose to explore the possibility to adapt in real time the parameters depending on the user's actions and physiological state. The objective is to match the best navigation parameters for each user in every situation in order to decrease cybersickness while still allowing efficient navigation. Compared to past work [1], we contribute in adapting the navigation method to users and not to the virtual environment, allowing us to propose a truly personalized navigation method.

2 ADAPTIVE NAVIGATION

2.1 Navigation Method

We use a Razer Hydra device, a joystick-based device, coupled with an Oculus Rift CV1 head-mounted display. We allocated the right joystick of the Razer Hydra to move forward/backward (z axis) and strafe left and right (x axis), while the left joystick allows rotation around the vertical axis (y axis).

We implemented an acceleration-based control, as it is the most natural way to move in a virtual environment. With this control, a position of a joystick corresponds to an acceleration, linear or rotational, implying to reach a speed limit depending on the properties and the topology of the virtual environment.

2.2 Cybersickness and Parameters Adaptation

To objectively evaluate cybersickness in real time, we chose the EDA as it is a simple value to measure and monitor in real time, and the EDA was shown to increase in the presence of cybersickness [7]. To measure the EDA, we use an E4 Empatica wristband [8].

We then need to adjust the navigation accelerations according to the change in the EDA. Adaptation is performed as follows: when the EDA increases, the acceleration factors decrease proportionally to the EDA's increase speed; and when the EDA decreases, the acceleration factors increase, which is described as follows:

$$A(t) = A\left(t_{-1}\right) - 0.5 \times \frac{dEDA(t)}{dt} \tag{1}$$

where $A\left(t_{-1}\right)$ and $A(t)$ are the accelerations, linear or rotational, at two successive frames, and the 0.5 factor has been determined empirically following simulations with different frequencies and amplitudes of the EDA variation in order to be adapted to the physiological reaction time of the EDA [10].

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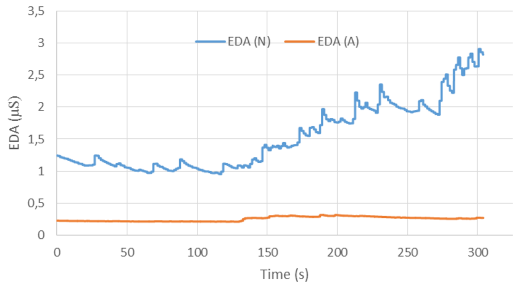

Figure 1: EDA evolution for one participant between both modalities

3 Pre-Study

3.1 Hypotheses

The purpose is to explore whether using adaptive navigation can have a effect on cybersickness, thus our hypotheses are: (H1) Adapting acceleration parameters from the EDA evolution limits EDA variations, and (H2) The adaptive control decreases cybersickness.

3.2 Virtual Environment

We designed a virtual environment so that cybersickness can be easily evaluated and induced by navigation tasks and not by any other factors. The virtual environment consists in a virtual forest with a gravel path. The path is 1.180 km long, so that the experiment can last enough time regarding cybersickness, and 5 m wide. The test application runs at 90 frames per second.

3.3 Procedure and Measurements

Seventeen participants (ages: 19-36) took part to the pre-study. They were asked to navigate in the virtual environment through two separate sessions in random order corresponding to two modalities, the normal modality (N) (without adaptation) as a reference and our adaptive modality (A). For each modality, participants were immersed the same amount of time, around 8 minutes.

During the simulation, the head movements, the virtual positions and orientations, and the time were logged. We computed the Motion-Sickness Dose Value (MSDV) [13], an EDA score computed over time considering the EDA variations between two frames, and the evolution of the Postural Stability (PS), defined as the ratio between the mean surfaces described by the projection of the center of gravity after and before exposures. Last, we asked participants to fill an SSQ before and after exposures.

3.4 Results

One participant could not finish the experiment and had to stop. Therefore, the results are expressed with 16 participants.

The mean values of the MSDV decreased from modality N to modality A for each motion axis: $MSDV_x = 37.7 \pm 7.6 \Rightarrow 33.3 \pm 7.6$, $MSDV_y = 36.0 \pm 7.1 \Rightarrow 32.1 \pm 7.4$ and $MSDV_z = 42.7 \pm 8.2 \Rightarrow 38.6 \pm 7.4$. Therefore, the manipulation of navigation parameters tends to affect the MSDV.

We observed a decrease in the mean values of the EDA from $2.19 \pm 2.24\mu$S.s with modality N to $1.09 \pm 2.18\mu$S.s with our method. Figure 1 shows an example for one participant of the EDA evolution for both modalities. It clearly shows that the EDA level is better controlled with adaptive navigation. It also shows that the manipulation of navigation parameters driven by the EDA level could have an effect on the EDA itself, which validates our proposal.

The PS did not present any evolution between both modalities, suggesting that adaptive navigation has no effect on postural stability.

Finally, the SSQ scores show an overall decrease of around 71% from modality N to our proposed modality.

4 Discussion

This pre-study provides promising results, as these seem to validate our hypotheses. If we observe the evolution of the acceleration parameters over time, some of the participants finished the adaptive navigation session with higher accelerations than they began, which proves that the adaptive modality adjusted navigation to the user and not to the environment, without changing the user experience.

5 Conclusion and Future Work

We showed that adapting navigation as a function of users' EDA could allow to decrease cybersickness without changing users' virtual reality experience.

Future studies include considering more participants in order to perform in-depth statistical analysis as well as investigating other cybersickness indicators to adapt navigation parameters.

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